China’s mobility path: disruptive technologies and their sustainability impacts

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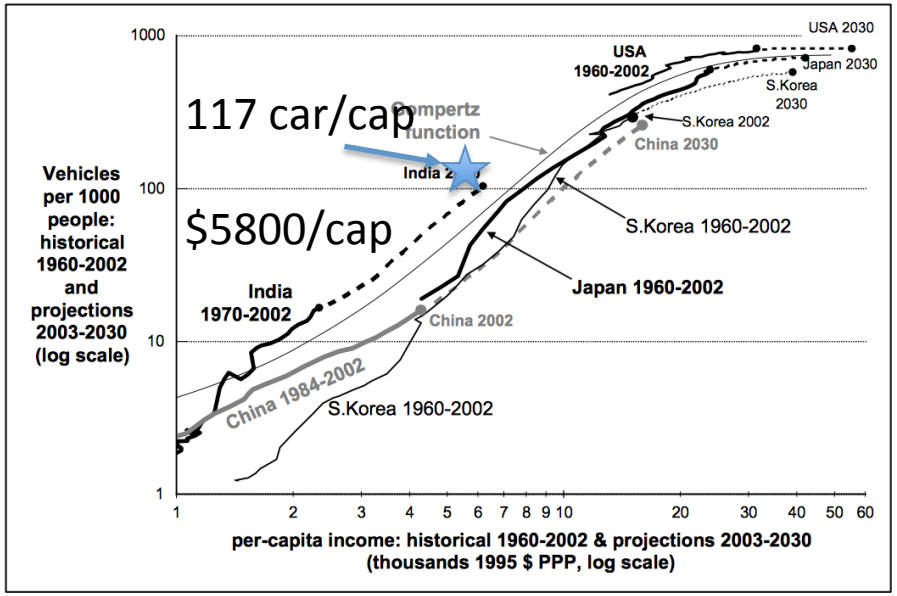
China's auto ownership is growing about as expected

Figure 10. Historical and Projected Growth for China, India, South Korea, Japan and USA: 1960-2030

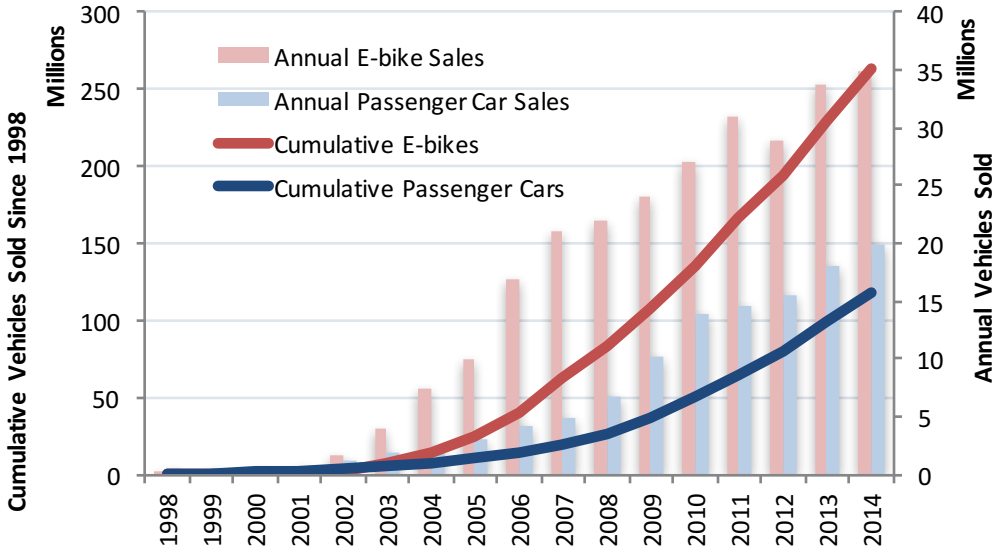


Dargay et al. 2007

Can disruptive technologies shift the curve?

China e-bike market

- Takeaway 1: e-bikes are the fastest and largest growth of alt-fuel in the history of motorization.



China e-bike technology

- Takeaway 2: e-bikes are the most energy (and CO_2) efficient motorized mode that exists

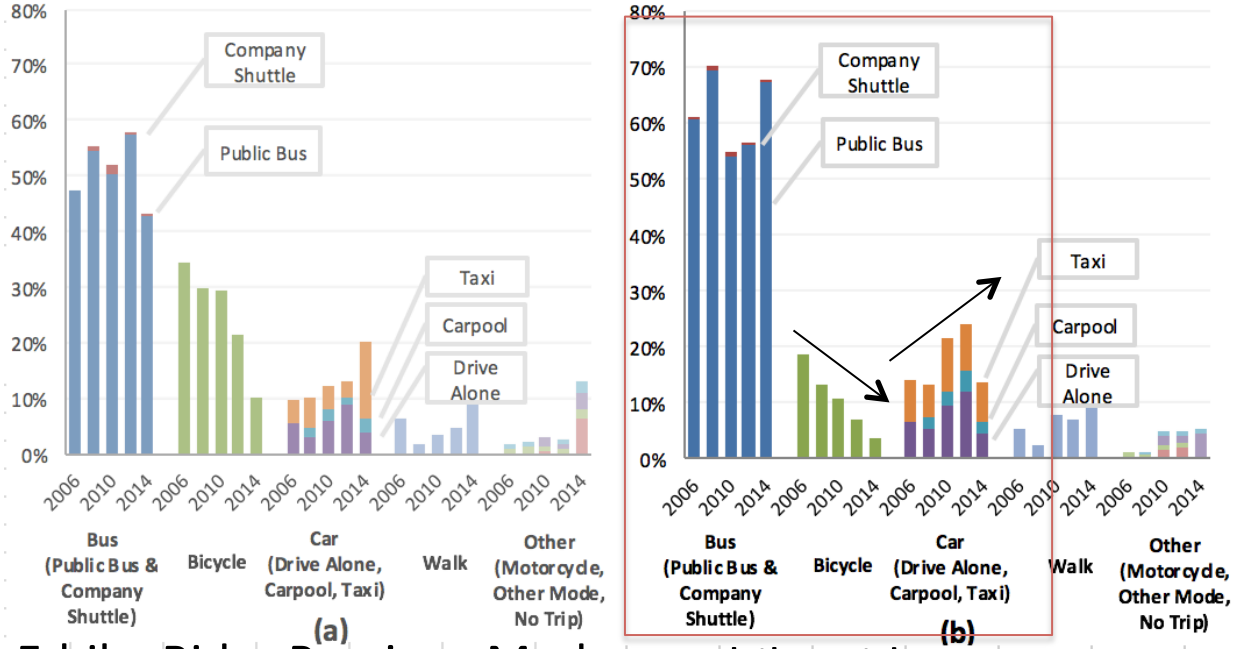
10x

4x

2x

Benefits Compared to What?

- Kunming China: bicycles dimming, car-based modes increasing



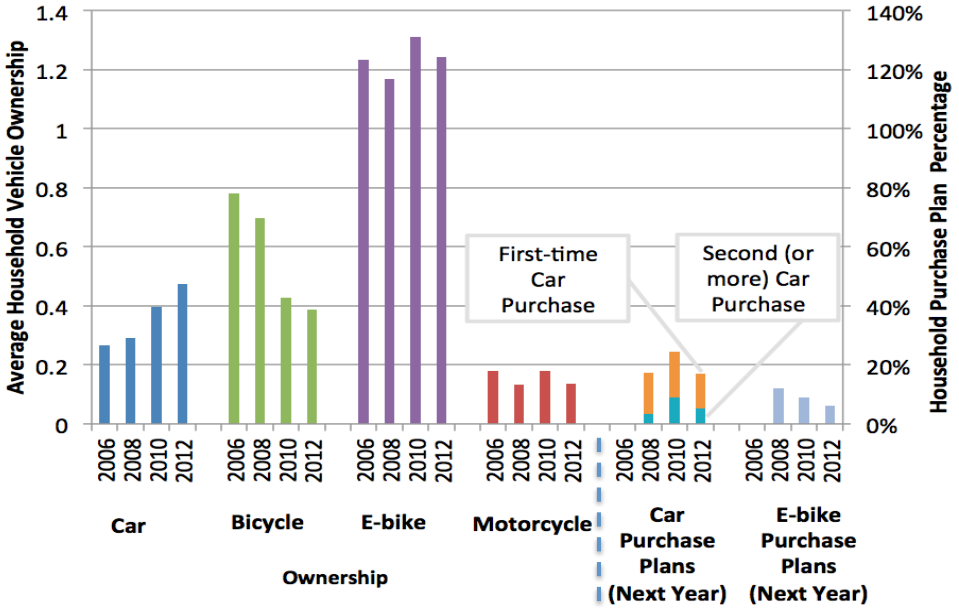
E-bike Rider Previous Mode

E-bike Rider Current Best Alternative

Cherry, C. R., Yang, H., Jones, L. R. & He, M. Dynamics of Electric bike ownership and use in Kunming, China. *Transport Policy* **45,** 127–135 (2016).

E-bike Riders: Future Car Owners

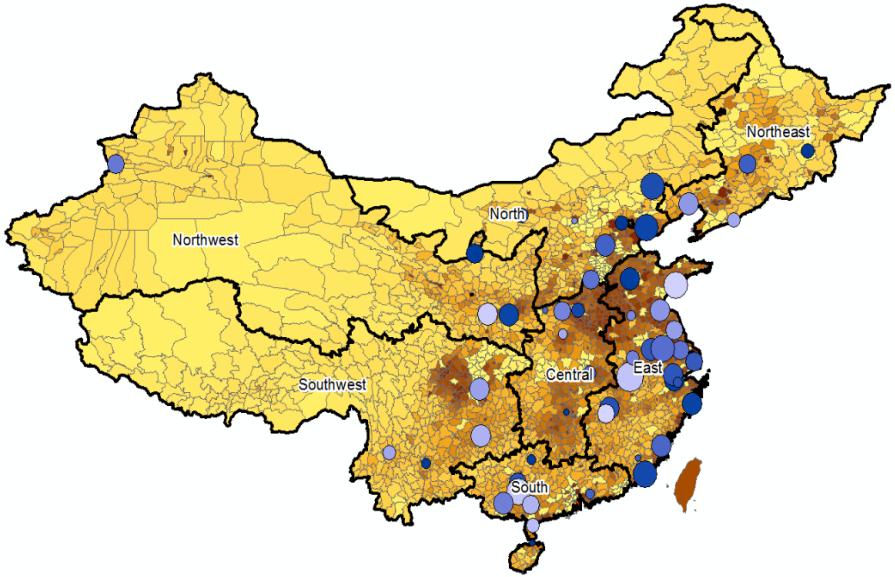
- Kunming: ~40% of e-bike riders have car in household, now more than bicycles and relatively large fraction plan to purchase



In Kunming: Household vehicle ownership and purchase plans.

E-bike Riders: Future Car Owners

- Our national telephone survey found similar results: HH car ownership (19-40%), purchase plans (8-30%).
- Hierarchical logit for car purchase: HH variables matter most, some city/regional-level data.



Car purchase model:

HH Parameter estimates:

+Income
+Licensed drivers
+Duration of motorized vehicle ownership

City Parameter estimates:

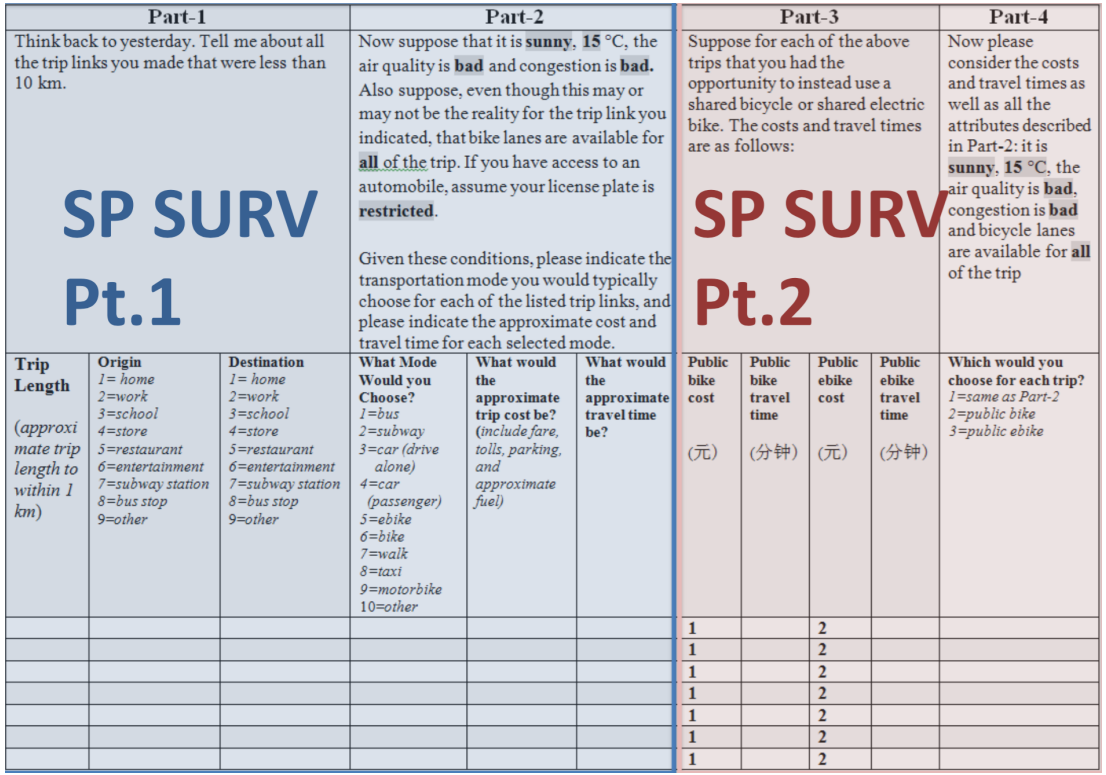
+GDP per capita
–Taxi density
–Bus density
+Number of cold days in winter

Regional Indicators:

+NW China

Ling, Z., Cherry, C. R., Yang, H. & Jones, L. R. *Transportation Research Part D* **41,** 50–63 (2015).

What about other tech



Part-1			Part-2			Part-3				Part-4
Think back to yesterday. Tell me about all the trip links you made that were less than 10 km. SP SURV Pt.1			Now suppose that it is **sunny**, **15** °C, the air quality is **bad** and congestion is **bad**. Also suppose, even though this may or may not be the reality for the trip link you indicated, that bike lanes are available for **all** of the trip. If you have access to an automobile, assume your license plate is **restricted**. Given these conditions, please indicate the transportation mode you would typically choose for each of the listed trip links, and please indicate the approximate cost and travel time for each selected mode.			Suppose for each of the above trips that you had the opportunity to instead use a shared bicycle or shared electric bike. The costs and travel times are as follows: SP SURV Pt.2				Now please consider the costs and travel times as well as all the attributes described in Part-2: it is **sunny**, **15** °C, the air quality is **bad**, congestion is **bad** and bicycle lanes are available for **all** of the trip
Trip Length *(approximate trip length to within 1 km)*	**Origin** *1= home 2=work 3=school 4=store 5=restaurant 6=entertainment 7=subway station 8=bus stop 9=other*	**Destination** *1= home 2=work 3=school 4=store 5=restaurant 6=entertainment 7=subway station 8=bus stop 9=other*	**What Mode Would you Choose?** *1=bus 2=subway 3=car (drive alone) 4=car (passenger) 5=ebike 6=bike 7=walk 8=taxi 9=motorbike 10=other*	**What would the approximate trip cost be?** *(include fare, tolls, parking, and approximate fuel)*	**What would the approximate travel time be?**	**Public bike cost** (元)	**Public bike travel time** (分钟)	**Public ebike cost** (元)	**Public ebike travel time** (分钟)	**Which would you choose for each trip?** *1=same as Part-2 2=public bike 3=public ebike*
						1		2		
						1		2		
						1		2		
						1		2		
						1		2		
						1		2		
						1		2		

- Carshare and (e-)bikeshare SP
  - We developed a survey instrument to pivot new technologies off of existing trips for a more realistic SP approach.

Campbell, A. A., Cherry, C., Ryerson, M. & Jones, L. Better Pen-and-Paper Surveys for Transportation Research in Developing Countries. *Transportation Research Record* **2405,** 42–48 (2014).

(e-)Bikeshare in Beijing

Table 6
MNL estimation results.

Variable	Switch to shared e-bike		Switch to shared bike	
	Parameter	(*p*-val)	Parameter	(*p*-val)
ASC_O	−6.31	(0.00)	−4.39	(0.00)
Distance (km)	−0.0854	(0.01)	−0.175	(0.02)
Air quality bad indicator * distance	Fixed	(Fixed)	Fixed	(Fixed)
Air quality medium indicator * distance	0.0194	(0.53)	0.158	(0.04)
Air quality good indicator * distance	−0.0153	(0.66)	0.133	(0.06)
Congestion indicator	−0.581	(0.01)	0.169	(0.57)
Congestion indicator * female indicator	0.812	(0.05)	0.563	(0.25)
License plate restriction indicator	−0.066	(0.72)	0.415	(0.07)
Heavy rain indicator	Fixed	(Fixed)	Fixed	(Fixed)
Light rain indicator	0.527	(0.02)	0.78	(0.01)
No rain indicator	1.17	(0.00)	1.03	(0.00)
Temperature cold indicator * distance	−0.0247	(0.49)	−0.0907	(0.10)
Temperature hot indicator * distance	0.000619	(0.98)	−0.218	(0.00)
Temperature comfortable indicator * distance	Fixed	(Fixed)	Fixed	(Fixed)
Original mode sheltered indicator	Fixed	(Fixed)	Fixed	(Fixed)
Original mode not sheltered indicator	0.308	(0.19)	0.874	(0.01)
Original trip link by bus	1.67	(0.00)	0.632	(0.16)
Original trip link was transit feeder	0.319	(0.14)	−0.156	(0.54)
Original trip link did not involve transit	Fixed	(Fixed)	Fixed	(Fixed)
Original trip link by subway	0.696	(0.11)	−1.14	(0.27)
Age	0.321	(0.00)	0.0731	(0.07)
Age squared	−0.00451	(0.00)	−0.000907	(0.05)
Higher education indicator	−0.686	(0.00)	0.221	(0.40)
Environmental concern indicator	0.811	(0.00)	0.35	(0.11)
Gender female indicator	−0.783	(0.02)	−0.356	(0.39)
Income	−0.132	(0.00)	−0.0201	(0.54)
Number of observations = 1181				
Number of parameters estimated = 42				
Log likelihood = 1154.154				
Adjusted rho-square = 0.412				

Shading corresponds to the five variable types: alternative specific constant, trip attribute (distance), environmental conditions, travel behavior, and demographics.

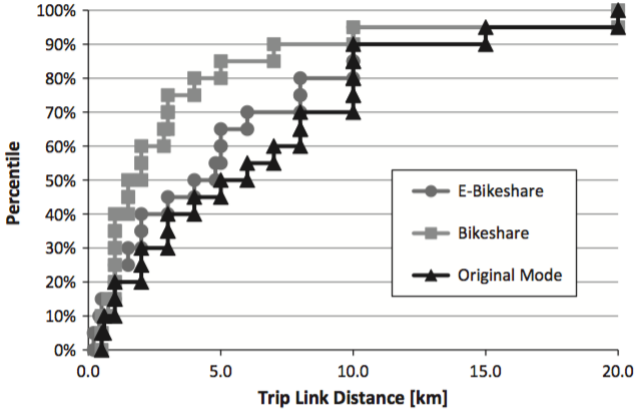


Fig. 2. Trip link distance CDF. * Reported trip links greater than 20 km have been removed.

Campbell, A. A., Cherry, C. R., Ryerson, M. S. & Yang, X. Transportation Research Part C. *Transportation Research Part C* **67,** 399–414 (2016).

(e-)carshare in Beijing

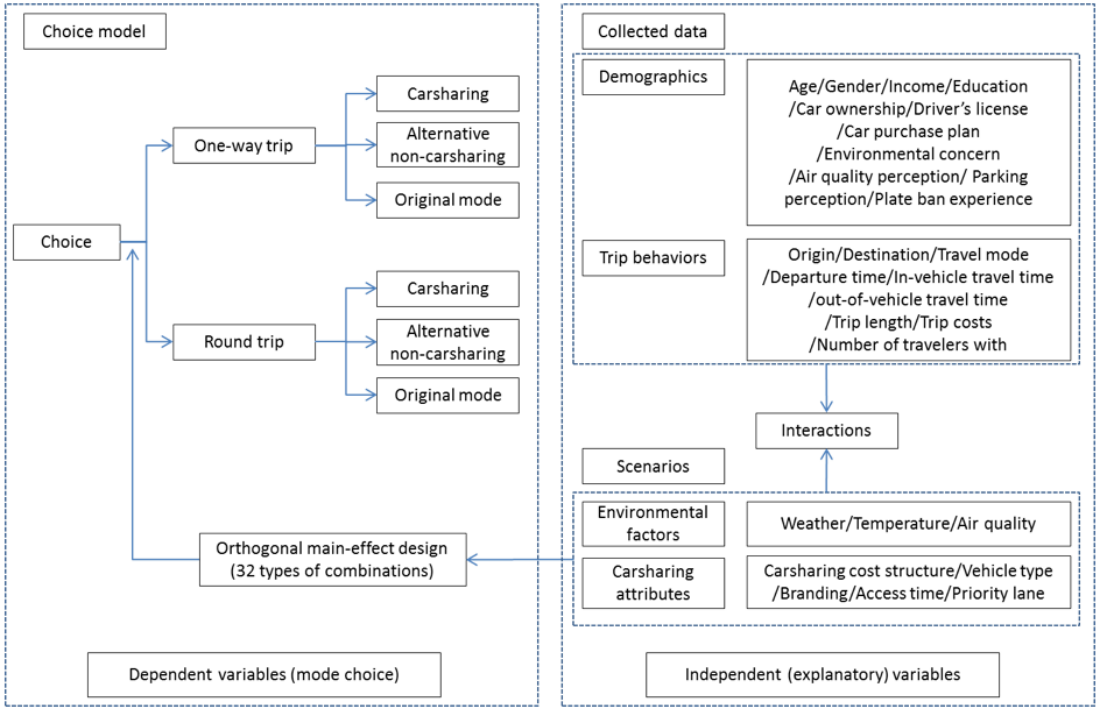


Table 1 Variable levels for stated preference carsharing and environmental attributes

	Factor Level			
	1	2	3	4
Vehicle Type	Battery EV	Gasoline	n/a	n/a
Decals	No	Yes	n/a	n/a
Precipitation	Sunny	Light Rainy	Rainy	n/a
Temperature	0 °C	10 °C	20 °C	30 °C
Air Quality	Good	Moderate	Unhealthy	Hazardous
Access Time	0	5 minutes	10 minutes	15 minutes
Travel Time	No priority lane (Peak/Off-peak)	Priority lane exists (Peak/Off-peak)	n/a	n/a
Cost (part 2)	Structure C	Structure D	Structure E	n/a
Cost (part 3)	12 RMB*/hour (F)	15 RMB/hour (G)	18 RMB/hour (H)	n/a

* RMB is an abbreviation of Renminbi, the official currency of China.

Notable Variables

HH Parameter estimate:

+Age

+No Car

+Gated Community

Transportation Attribute estimates:

+Group traveler

+Bad Perceived Parking

+Cost Advantage

Weather Indicators:

+Cold

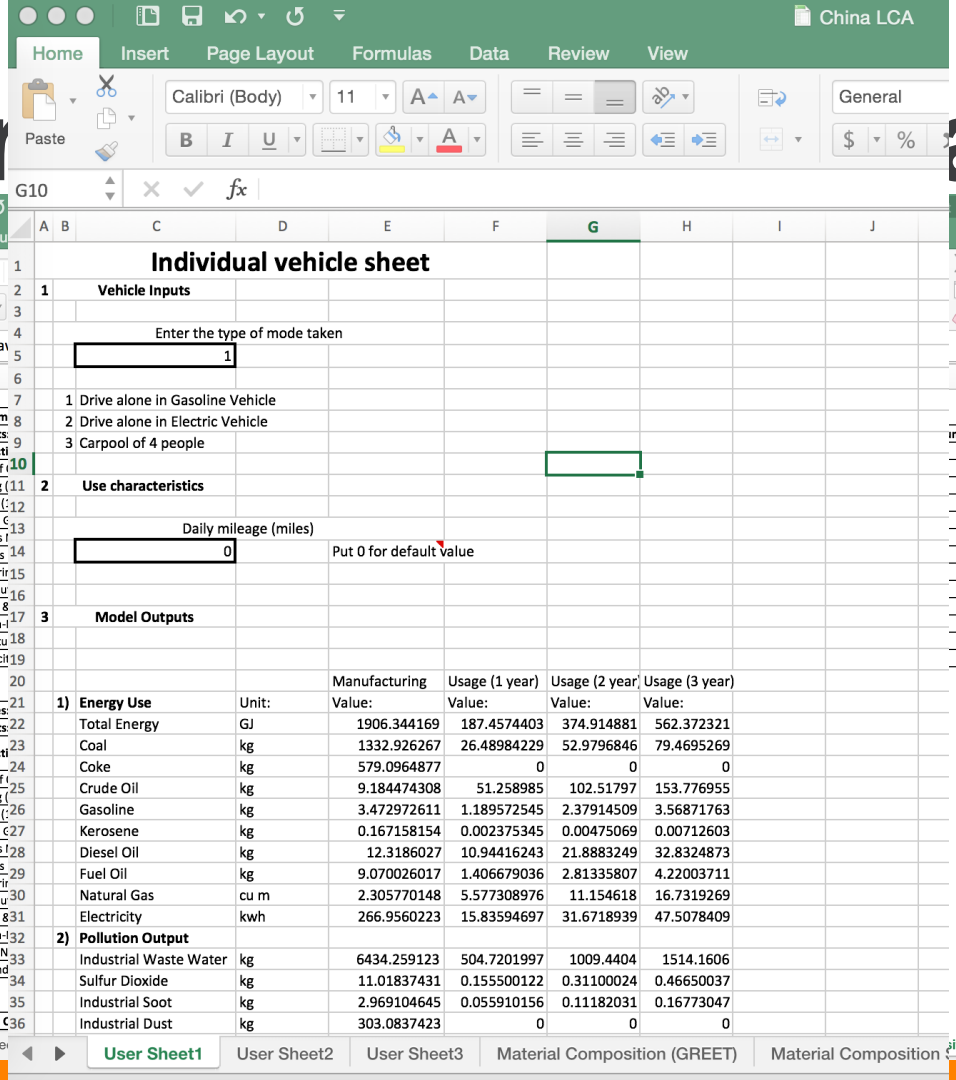
Yoon, T., Cherry, C. R., Jones, L. One-way and round-trip carsharing: a stated preference experiment in Beijing (in review)

Pivot to Environment

One of our main interests is how new technologies:

1) shift behavior and
2) change sustainability outcomes of China's transport

LCI Fr ant



Individual vehicle sheet

1 Vehicle Inputs

Enter the type of mode taken: 1

1 Drive alone in Gasoline Vehicle
2 Drive alone in Electric Vehicle
3 Carpool of 4 people

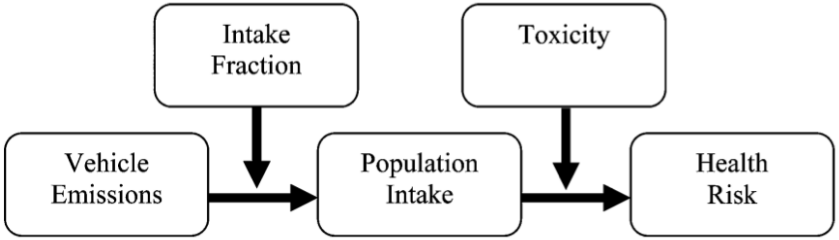
2 Use characteristics

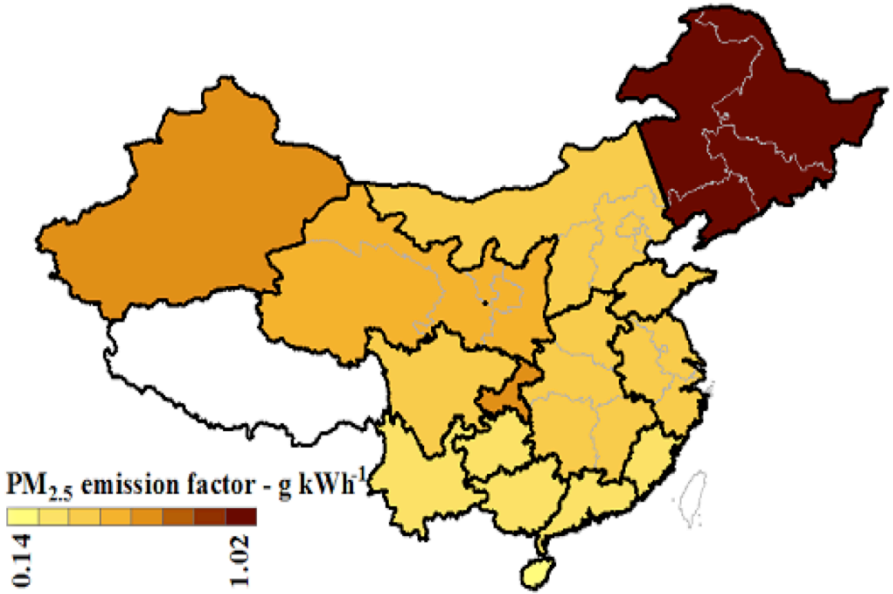
Daily mileage (miles): 0 — Put 0 for default value

3 Model Outputs

			Manufacturing	Usage (1 year)	Usage (2 year)	Usage (3 year)
1)	**Energy Use**	Unit:	Value:	Value:	Value:	Value:
	Total Energy	GJ	1906.344169	187.4574403	374.914881	562.372321
	Coal	kg	1332.926267	26.48984229	52.9796846	79.4695269
	Coke	kg	579.0964877	0	0	0
	Crude Oil	kg	9.184474308	51.258985	102.51797	153.776955
	Gasoline	kg	3.472972611	1.189572545	2.37914509	3.56871763
	Kerosene	kg	0.167158154	0.002375345	0.00475069	0.00712603
	Diesel Oil	kg	12.3186027	10.94416243	21.8883249	32.8324873
	Fuel Oil	kg	9.070026017	1.406679036	2.81335807	4.22003711
	Natural Gas	cu m	2.305770148	5.577308976	11.154618	16.7319269
	Electricity	kwh	266.9560223	15.83594697	31.6718939	47.5078409
2)	**Pollution Output**					
	Industrial Waste Water	kg	6434.259123	504.7201997	1009.4404	1514.1606
	Sulfur Dioxide	kg	11.01837431	0.155500122	0.31100024	0.46650037
	Industrial Soot	kg	2.969104645	0.055910156	0.11182031	0.16773047
	Industrial Dust	kg	303.0837423	0	0	0

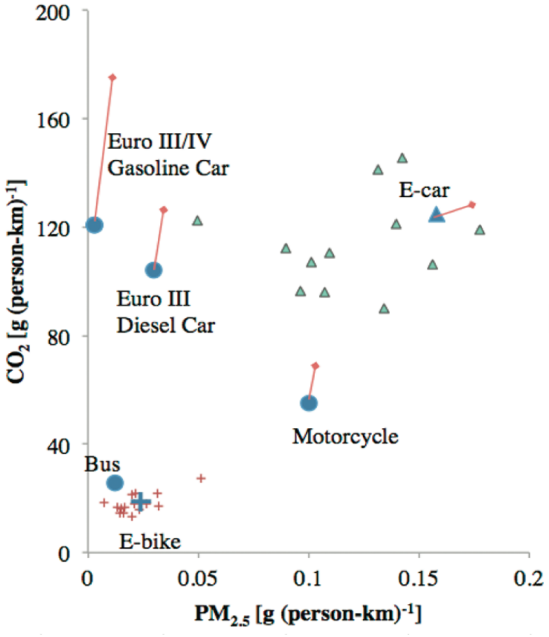
Emerging EVs Require Regional (and Exposure) Models

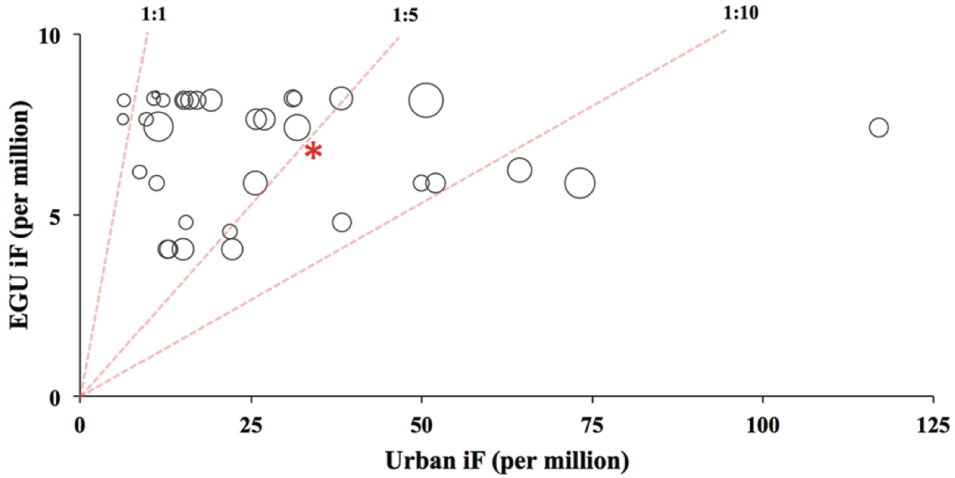




Ji, S., Cherry, C. R., J Bechle, M., WU, Y. & Marshall, J. D. Electric Vehicles in China: Emissions and Health Impacts. *Environ Sci Technol* 120201084401001 (2012).

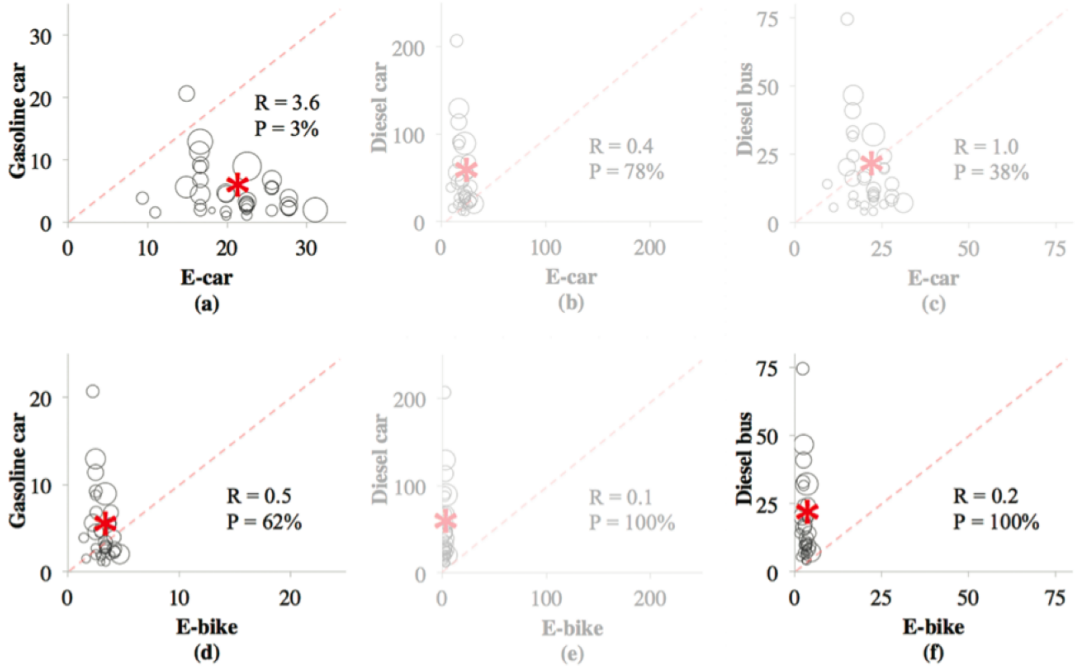
Emerging EVs Require Regional (and Exposure) Models





Emerging EVs Require Regional (and Exposure) Models

Relative Mortality Impacts of $PM_{2.5}$



Environmental Justice impacts also important

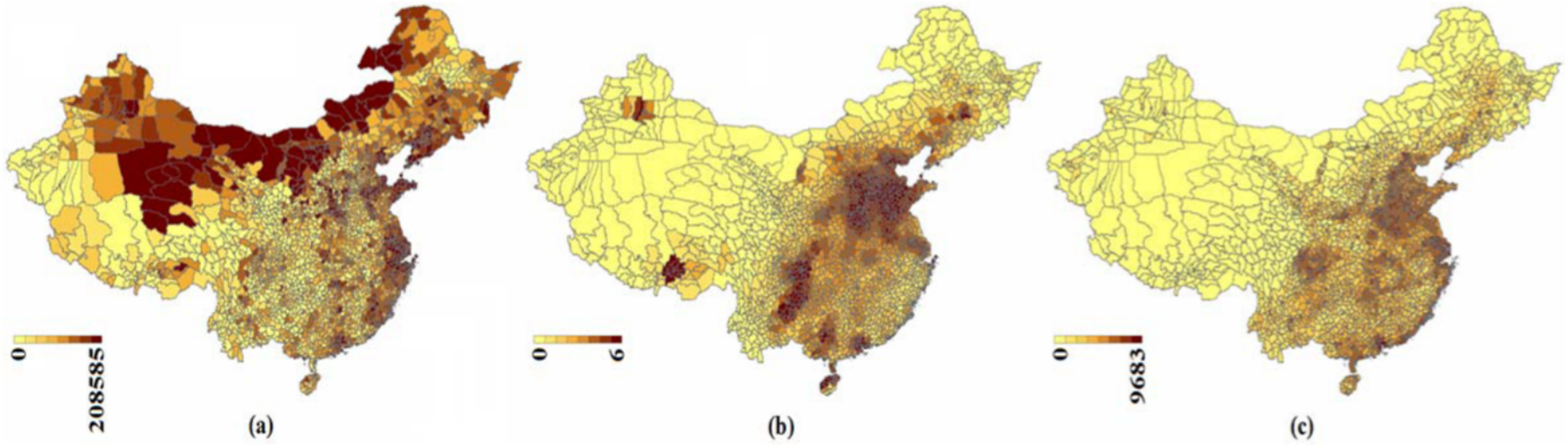
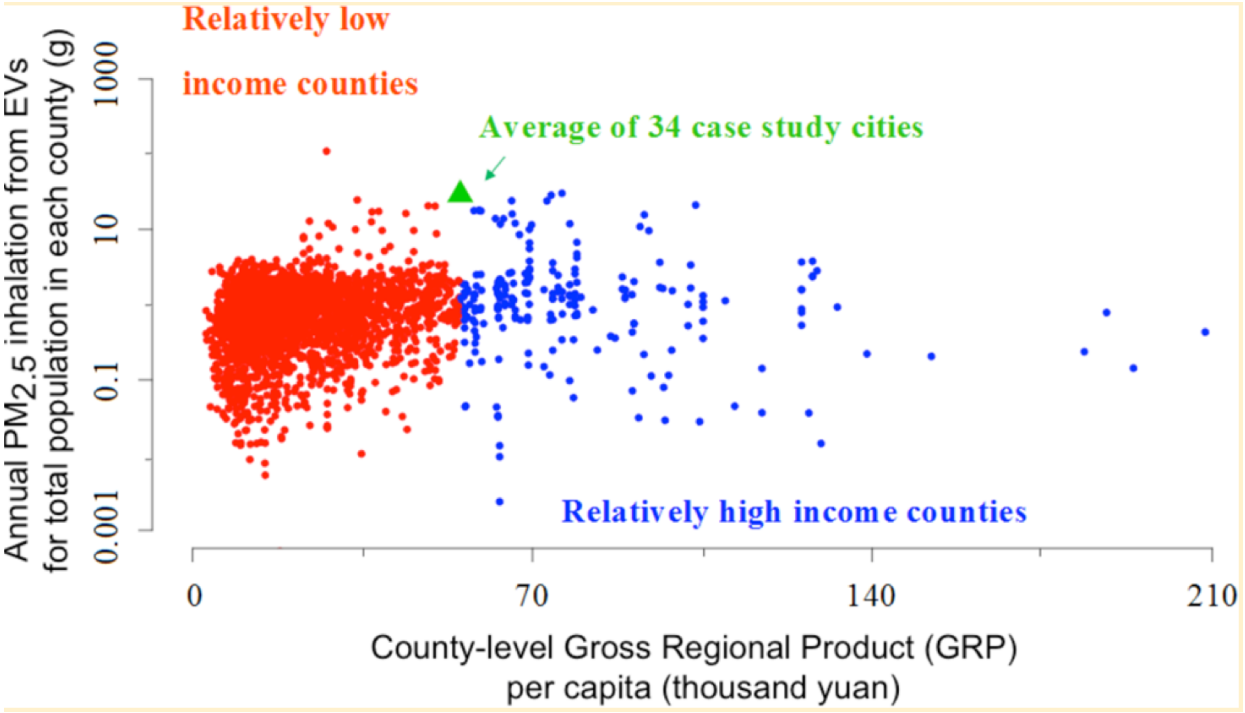


Figure 1. (a) Per capita gross regional product (in RMB) by county in China (darker color corresponds to higher values); (b) Per capita inhalation from coal power plants (μg $PM_{2.5}$ from 10^9 vehicle kilometers traveled by EVs in each of 16 power grids); (c) Population density (people km^{-2}).

Ji, S. *et al.* Environmental Justice Aspects of Exposure to PM 2.5Emissions from Electric Vehicle Use in China. *Environ Sci Technol* **49,** 13912–13920 (2015).

Environmental Justice impacts also important



Notable EJ Findings

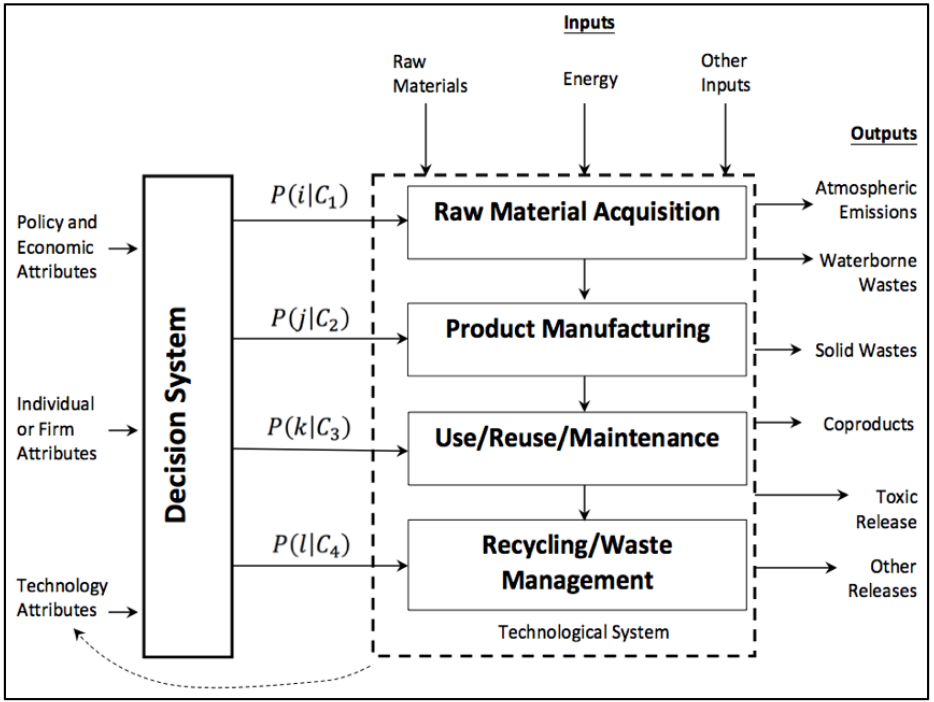
- 77% of EV urban emissions are inhaled by more rural (less affluent) populations
- 5% of EV urban emissions inhaled by lowest 10th% income
- Inhalation correlated with other socio-economic indicators (literacy, family size, age, minority).
- Sensitivity analysis: clean dirty/ small coal plants or those close to cities. Dirty/small best for EJ and total health outcomes

EV recommendations in coal-powered China

- Even dirty e-bikes are cleaner than all other motorized modes
- E-cars still use a lot of energy and move emissions to power sector
- Cleaning up the power sector is important parallel step
- Technologies to reduce urban car use can help (shared cars, bikes, e-bikes)
- EVs are only getting cleaner
- E-cars have promise if indeed personal cars are inevitable
- E-bikes are more than just fancy bicycles in shared systems

Behavior matters

Behavior matters with new tech



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Much of this research was funded by the National Science Foundation under grant CBET-1055282

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